Adsorption of Acid Red 18 Dye from Water Using Natural Adsorbents: Isotherm, Kinetics and Optimization Studies

SHORT SYNOPSIS

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Certificate

I hereby declare that the Short Synopsis "Adsorption of Acid Red 18 dye from water using natural adsorbents: Isotherm, kinetics and optimization studies" being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in the Department of Applied Sciences (Chemistry) under School of Engineering and Technology of Manav Rachna International Institute of Research & Studies, Faridabad during the academic year 2023-24. It is a bona fide record of original work carried out under the supervision of Dr. Rajeev Kumar and Dr. Jyoti Chawla has not been submitted in full or part to any other university or institute for degree or diploma. Further, it is certified that Short Synopsis is plagiarism free and proof has been submitted.

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ABSTRACT

Pollution in water due to dyes is a significant environmental concern. Dyes are particularly used in the fabric industry. The function of dyes is to color the fabrics and other colorable materials, but many of them are chemical based and hazardous to all the living beings including environment. These dyes may enter the waterways during the manufacturing or dyeing process or when clothes are laundered. Dyes can be toxic to aquatic life, disrupting ecosystems and harming organisms. Acidic dyes are one of the primary types found in untreated water effluents. A variety of methods and technologies are available for removal the acidic dyes from wastewater. Advancements in environmental remediation technologies areongoing, and new developments may have occurred. Conventional and potentially emergingtechnologies have been significantly developed for removing acidic dyes from wastewater. Adsorption technology can be successfully applied for adsorption of dyes from water using various sorbent materials.Synthesized or modified adsorbents are frequently used to remove acidic dyes from water. Low efficiency, high cost, and hazardous nature are the main limitations associated with synthesized adsorbents. The present work is focused on the identification of natural materials for removal or adsorption of acidic dye Acid Red 18 (AR 18) from water effectively. Adsorbent performance will also be increased by modification of natural adsorbent withintroduction of more active groups on the adsorbent. Performance and presence of active groups on the adsorbents will beanalyzed using various spectral techniques. Batch study will be performed for maximum removal of AR 18 dye from water at various parameters. Performance comparison of natural and modified natural adsorbents will also be done with other reported adsorbents.

Keywords: Acidic dyes, Acid Red 18, Adsorption, Batch study, Isotherm models, Kinetic model, Natural adsorbent, Response surface methodology

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1. DESCRIPTION OF BROAD AREA

One of the major global issues is water pollution caused by release of untreated wastewater from different industrial sectors. Fabric, paint, cosmetics, paper, food and many more industries use syntheticdyes due to their vibrant colors and easy applications. Among these industries, the textile industry is reported to use the most dye, with an estimated global usage of around 10,000 tonnes annually and generate approximately 100 tonnes of dye effluent per year.These colored effluents, when discharged into water-bodies without treatment result in water pollution. This wastewater can contain significant amounts of colored and toxic substances, including carcinogens, posing a serious threat to environment. Artificial dyes have a great impact on water quality.

A World Bank analysis estimates that the dyeing and treatment of textiles is responsible for more than 18% of the world's industrial water pollution.Annually thousands dyeswith different characteristics have been applied in different industries. Shockingly, only a small percentage of these dyes are properly treatedprior to being released into water bodies, leading to widespread water contamination. Further breakdown of some dyes results in harmful by-products, which contaminate water and pose a greater risk to human health.

Acid dyes are a class of synthetic azo (–N=N–)dyes that are water soluble and are mainly used to dye textiles, especially wool, silk, and nylon. Acid Red 18 (AR 18) is acidic dye highly used for dyeing of wool, silk, and nylon. Many treatment technologies (Precipitation, ion exchange, biological and chemical degradation, advance filtration and adsorption) are available for removing toxic contaminants and dyes from water systembut these have some efficiency, cost, and sustainable removal challenges.More investigation is required for more economical, ecological, and effective materials/methods, especially for treating large volumes of dye from wastewater system. Dye removal from water will also be very effective if the adsorbent is highly abundance, eco-friendly, less expensive and more efficient.

The aim of current work is to explore/preparelow costnovel green materials that can efficiently remove AR 18 dye from aqueous solutions. The removal parameters will also be optimized by response surface methodology (RSM) for optimal removal of AR 18 dye from water.

2. LITERATURE REVIEW

Untreated wastewater from a variety of industries being dumped into water is a worldwide issue that affects everyone (Lellis et al., 2019). Synthetic dyes are actively applied in industries such as food, textile, paper, paint, tannery, cosmetics etc. because of their vibrant colors and easy application (Hanafi &Sapawe, 2020; Khehra et al., 2006). Among these industries, the textile industry is reported to use the most dye, with an estimated global usage of around 10,000 tonnes annually and generate approx. 100 tonnes of dye effluent per year (Katheresan et al., 2018; Hamidi et al., 2022, Piaskowski et al., 2018). Untreated discharge of these colored effluentsinto water-bodies results in water pollution (Lellis et al., 2019). This wastewater can contain significant amounts of colored and toxic substances, including carcinogens, posing a serious threat to environment (Latif et al., 2023).

Artificial dyes in wastewater have a great impact on water sources. According to a report by the World Bank, worldwide more than 18% water pollution is due to untreated water effluents being dumped into water resources from fabric industries.Around 10000 types of colorants are being used in various industries, with over $7x10^5$ tons of synthetic dyes produced annually worldwide. Shockingly, only a small percentage of these colorants are satisfactorilytaking care of before being released into water bodies, leading to widespread contamination. Further breakdown of some dyes results in harmful by-products, which affects the water quality by contaminating it and pose a greater risk to human health.

It’s important to identify the fate and transport of unused dyes in aquatic environments, including their degradation pathways, persistence, and bioaccumulation potential and determine the ecological impacts of dye pollution in water biodiversity, including effects on aquatic organisms, food webs, and ecosystem health. Monitoring is key tool to detect and quantify dye pollution in water bodies and development of more stringent regulations and guidelines to control dye discharge.

Dyecontains various organic groups which absorb light within the visible spectrum, thereby manifesting distinct coloration (Benkhaya et al., 2020). Method of production of dyes determines whether they are synthetic or natural. Natural dyes can be extracted from natural derivatives obtained from plants, animals, insects and minerals without any chemical treatment (Affat, 2021) while synthetic dyes are manmade and are produced from chemical compounds such as mercury, lead, chromium, petrochemicals etc. Fabric industries are categorized as the

10th most polluting sector for wastewater pollution due to untreated water effluents (Wong et al., 2020).

Dyes contain a group of atoms known as chomophore which impartscolor to its substrate and auxochromes which enhance their affinity towards the substrate (Salleh et al., 2011). Dyes can be classified into three main type's i.e. anionic, cationic and non-ionic dyes (Salleh et al., 2021).

Anionic dyes are acidic in nature and generated negatively charged ions in water after dissociation of these dyes, e.g. Methyl Orange (MO), Acid Red 18 (AR 18), Indigo Carmine (IC), Congo Red (CR), Reactive Black 5 (RB 5)etc. (Egbosiuba, 2022). These include acid, direct and reactive dyes. However, cationic dyes are basic in nature and generate positively charged ions in water after dissociation of these dyese.g. Methylene Blue (MB), Crystal Violet (CV), Rhodamine 6G (R 6G), Malachite Green (MG)etc. (Kadhom et al.,2020). Non-ionic dyes are generally neutral in nature and have low solubility in water e.g. Disperse Blue 56 (DB 56), Disperse Red 11 (DR 11) etc. (Egbosiuba, 2022, Kadhom et al.,2020).

Acidic and basic dyesare highly watersoluble (Liu Quiang, 2020), which making them difficult to removeusing conventional removal methods. According to their chemical structure and properties, acidic dyes can be classified into different types. The most common types are azo dyes, triarylmethane dyes and anthraquinone dyes. Every dye has specific application because of unique chemical structure and properties. Textile industry primarily uses azo dyes accounting for approximately 70% of total dye usage (Adesanmi et al., 2022; Benkhaya et al., 2020). This class of dyes is characterized by its affordability, high stability and solubility, possibly featuring one or more N-N bands. Furthermore, these dyes exhibit non-degradability and robust resistance to heat and sun light, chemicals, and reactive agents (Chaleshtori et al., 2017).

Acidic dyes are applied to color natural protein fibres, silk, wool, synthetic nylon and various blends of these fibres in textile industries (Moody et. al., 2004). Acidic dyes work under acidic or neutral conditions and are characterized by superior chemical and photochemical stability (Yao et al., 2018; Richards, 2012). Dye treated water when discharged in water-bodies cause not only aesthetic damage to them but also affects the underlying flora and fauna by disrupting the penetration of light through water (Lellis et al., 2019). Apart from this a certain amount of applicable dye (approx. 15-50%) which do not bind to the fabric and is released in discharged effluents affects the microbes of soil strata and affects plant growth if it finds a way to soil

(Meghwal et. al., 2020). The toxic and carcinogenic nature of acidic dyes is because of aromatic compounds which block the access of light in water thus affecting photosynthetic activity in aquatic organisms (Gupta & Suhas, 2009). Acidic dyes can create problems with the kidneys, liver, brain, and reproductive system when come in contact with humans (Chaleshtori et al., 2017). Thus, mitigation of azo dyes from wastewater is a significant environmental concern.

Conventional techniques for mitigation of dye have certain limitations including generation of toxic sludge, high startup and maintenance costs and low removal efficiency (Hussain et al., 2022; Dutta et al., 2021; Yahiaoui et al., 2021; Sardar et al., 2021). Also due to wide range of dyes and additional chemicals present in industrial effluent besides the dye itself, individual treatment methods might not be fully effective on their own.

On the other hand, non-conventional methods such as membrane filtration, biologicaltreatment using microorganisms like bacteria's, and chemical oxidation have great attention to remove toxic materials and dyes from polluted water (Aragaw& Bogale, 2021). Advanced oxidation processes involve the generation of highly reactive hydroxyl radicals to break down dyes into harmless by-products (Saharan et al., 2014).Biological treatment methods harness the natural ability of microorganisms to degrade dyes, offering a sustainable approach to wastewater treatment. These techniques effectively eliminate dyes that are resistant to traditional techniques.

Recently, adsorption techniques have gained favor as they overcome majority of the limitations of physicochemical methods. Easyavailable and facile modification of the adsorbent further enhances the benefits of the method (Bulgariu et al., 2019). Straightforward operation of adsorption process and the versatility in utilizing various natural or synthetic sorbents make adsorption most opted process (Dousova et al., 2024).Adsorbents can be natural, synthetic, natural modified or synthetic modified.

Commercially activated carbon (AC) is widely available adsorbent due to large surface area and micropore volume but its large scale use is limited due to rapid saturation (Jozwiak& Filipkowska, 2024), high cost and less regeneration ability (Philippou et al., 2021). Though AC obtained from biomass is found to be an economically and sustainably viable solution but its usage is limited because of small pore size thus resulting in large amount usage of adsorbent (Li et al., 2022). Furthermore, the development of novel adsorbent materials such as graphene based composites, metal organic frameworks, and an activated carbon derivative has demonstrated

remarkable performance in capturing and removing acidic dyes from wastewater. Recent studies have shown how surface modification by reactive groups can significantly improve the performance of adsorbents (Shin et al., 2022,Jiang et al., 2022).Anionic, cationic, neutral and polymeric groups are actively used for surface modification of adsorbent.

Notably, adsorbents exclusively engineered through these alterations have demonstrated remarkable efficacy in mitigation of dyes and heavy metals from aqueous system (Wong et al., 2020). These advanced adsorbents offer excellent adsorption capacity (Qmax) for mitigation of complex dye mixtures and highly soluble dyes from aqueous system due to presence of active groups and high surface areas.

Research is going on to identify synthetic, natural and modified materials that can serve as cost-effective and more efficient adsorbents. Different kinds of materials were synthesized for mitigation of unused dyes from aqueous medium at various parameters. Bazrafshan et al., 2012 used SWCN (single walled carbon nanotubes) for RR 120 dye removal from water with Qmax of 426.49 mg/g at specific parameters (initial 50mg/L, RR 120concentration, 180 minutes time and 23 ± 2∘ C temp.).Mohammadi et al., 2020 performed a study for Disperse Blue 56 dye removal using a novel adsorbent, ZSM-5(ZnO magnetic) under optimal conditions of pH3, sorbent dose 0.015g and initial dye concentration 10^{-5}M for 91% dye removal.Dassaa et al., 2020 studied electro-coagulation using aluminium electrodes to remove Disperse Blue 56 (DB56) from water with approx. 98% efficiency.

Qian & Song2005 analyzed adsorption behaviors of Disperse Red 60 and Disperse Orange 76 on elastic polyurethranefibre at 90ºC. Li et al., 2010 conducted a study investigating usage of bentonite complex, obtained by combining bentonite and polyepicholorohydrin-dimethylamine for 95%removal of anionic dyes (Acid Dark Blue 2G and Reactive Violet K-3R) and non-ionoic dyes (Disperse Blue SBL and Vat Scarlet R) from aqueous solutions.Adsorption capacity and removal efficiency were also be increased by modification of synthetic materials.

Luna et al., 2021 synthesized hybrid aerogel by combining Linde Type Azeolite particles with chitosan-based aerogel for removal of two different nature dyes (Cationic and anionic) from water. The Qmax was observed 103 and 43mg/g for Indigo carmine and Rhodamine 6G respectively. Shin et al., 2022 developed polyvinylidene fluoride membranes modified using iron oxide nanomaterials coated with chitosan (Fe-PVDF) to remove Evans Blue dye (EB, anionic) and found maximum removal efficiency of 434.78 mg/g at low values of pH.

Jiang et al., 2022 cross-linked lignosulfonate and carboxylated chitosan to synthesize hybrid lignin (HL) and modified it using polyvinylpolyaminefor anionic dyes removal from water.Zhang et al., 2023 synthesizedmesopoprous carbon containing iron composite (Fe-MC) composites by the reduction of carbothermal for CR dye removal. 97.2 % CR dye was removed with Qmax of 972.1 mg/g.

Zhang et al., 2024 modified raw lignin nanoadsorbents by treating with polyethylenimine to remove Sulforhodamine B (anionic) dye from water. Under acidic conditions (pH 2.2) a Qmax of 143.88 mg/g was observed and the adsorbent could be reused for up to three cyclesafter treating it with NaOH.

To avoid large use of hazardous chemical and reduce the cost of overall process natural and natural waste materials were applied as effective materials for mitigation of dyes and toxic compounds from water system. Household waste such as rice husk, fruits and various vegetables peels have been applied as adsorbent for removal of various dyes in different conditions. Other than household waste materials, plant waste, roots, activated carbons of different parts of tree and plants have been actively used for removal of harmful dyes from wastewater.

Bencheqroun et al., 2019 conducted a study to investigate the potential of natural Moroccan clay as an adsorbent for eliminating Astrazon Blue BG and Astrazon Yellow 7GLL (Basic dyes) from water. Qmax was observed to be 101 and 127mg/g for BG and YL respectively at 25^0C.Filho et al., 2021 used marine shell waste adsorbent forBright Blue Acidand Reactive Red 133. 93%removal was observedat specific conditions.Ozacar&Şengil, 2004 studied the removal of various disperse dyes using alunite.Qmax obtained were 498 mg/g (Disperse Blue 56), 525 mg/g (Disperse Red 74) and 500 mg/g (Disperse Yellow 119) respectively at pH 3.

Arivoliet al., 2008 used AC prepared from Aloe Barbadensis Mill to remove Congo Red (CR), Rose Bengal (RB), Malachite Green (MG), Rhodamine B (RDB) dyes to observe the effect of various parameters on their removal. Okoli et al., 2015 prepared AC using the seeds of Tamarindus Indica and utilized to remove Orange G and Safranin O dyes from water and observed that different parameters affected (pH, dosage, concentration and time) the removal efficiency of tamarind seed.Dimbo et al., 2024 prepared AC by using SpathodeaCampanulata for adsorption of Methylene Blue (MB) from wastewater. Optimal conditions for 99.95% dye removal were found at various parameters i.e.90mg/L (dye initial conc.), 0.2 g/100 mL (adsorbent dose), 120 min. (contact time) and 9 (pH).

Temesgen et al., 2018 applied activated peels of fruits for removal of Reactive Red dye. After conducting various batch studies, they found that 89.41% and 70.25% removal was achieved under optimized conditions (pH 4, adsorbent dosage, 1g/100ml, initial dye concentration, 25mg/L and temperature, 30°C) using activated orange and banana peels respectively.Soliman et al., 2019 used moringa seeds waste (MSW) to removeRed 60 dispersed (DR60) and CR dyes and found that maximum amount of dye adsorbed for CR and DR60was 170.7 and 196.8 mg/g respectively at constant variables (100mg/L dye concentration, 25 °C temperature and pH 7).

Wong et al., 2020 used coffee waste adsorbent modified with polyethylenimine for CR and RB5 removal from water. Maximum removal of these dyes was obtained at 50 minutes for RB5 and 106 minutes for CR dye respectively. Qmax was calculated using Langmuir isotherm with 77.52 and 34.36 mg/g for both of the dyes respectively.

Sterenzonet al., 2021 investigated upon usage of pine tree biochar for adsorption of acidic dyefrom wastewater effluent with almost 100% removal at biochar dose of 10g/L. Latif et al., 2018 used common agro waste i.e., watermelon (Citrullus Lanatus) peels (WMP) for fluorescein and eosin dyes.Maximum 88.08% and 79.31% removal was achieved for fluorescein and eosin dye respectively using the agro waste.

Alarcon et al., 2022 worked with an adsorbent prepared from orange seed powder by removing lipids using hexane extraction to remove dyes from textile wastewater. They observed more than 95% removal efficiency under optimized conditions (pH 2.6, adsorbent dosage of 0.58 g/L and temperature 26 °C).

Talukdar and Sarma, conducted a study to removeMB and CR dye from wastewater released by textile industry using the powdered leaves of the Burflower (NeolamarckiaCadamba) tree with removal percentages of the 76.35% for CR and 85.8% for MB.Budak, 2023 investigated the use of stem of Silybum Marianum plant and its modified form (carbonized at 800^0C) for Basic Blue 3 and Basic Yellow 28from water effluents and observed approx. 99% removal using carbonized form.Hassani et al., 2024 derived novel adsorbent from Aleppo Pine fibres (FPAs) to remove cationic dye, Blue Maxilon (BM) and anionic dye, Black Eriochrome (NE) from textile effluents. Maximum removal (93% for BM and 98% for NE) was obtained at pH 5.6 on 0.05 g/L adsorbent dose.

Natural materials are magical materials to maintain the sustainability of the environment and fulfill all the other eco-friendly requirements & abundance. These are sometimes modified to enhance the capability of the natural adsorbents. Recently researchers have been applied these magical materials for different proposes. Natural adsorbent is one of the applied fields of the natural materials.

Kamaci&Kamaci, 2024 prepared bioadsorbents using nanoparticles of sodium alginate and quince seed to remove MB from liquid effluents and observed Qmax of 192.3 mg/g at pH7 and temperature 60 °C.Qulatein& Yilmaz, 2023 used ulvalactuca marine algae and calcined eggshell adsorbents for cationic (MB) and anionic (CR) dyes from water.Qmax was observed 2000 mg/g for MB and CR dyes.Ramakrishnan et al., 2021 used naturally synthesized adsorbent by combining karaya gum sponge and chitosan for Methyl Orange (MO) and Methylene Blue (MB). Maximum capacity was observed at specific conditions. Qmax was calculated using Langmuir isotherm (32.81 mg/g for MO and 32.62 mg/g for MB) which decreased with increased pH from 5 to 10.

Synthetic as well as natural materials were used for AR 18 dye removal from water. We have systematically reviewed the materials proposed for removal of AR18 from water and identified the challenges and gaps in the area in context of their practical application.

Zare et al., 2024 synthesized graphene oxide-cobalt ferrite (GO-$CoFe_2O_4$) for AR 18 removal from aqueous solutions and performed batch studies to find optimal conditions (pH 5, adsorbent dosage 1 g/L, initial concentration 25 mg/L) for Qmax of 40.77 mg/g.Hamidi et al., 2022 investigated upon usage of Granular Ferric Hydroxide (GFH) for adsorption of AR 18 dye and obtained 78.59 % removal at 2 g/L (adsorbent dosage), 5 (pH), 77.5 mg/l (initial dye concentration) and 85 min (contact time).Shirmardi et al., 2013 evaluated upon usage of SWCNT (single wall carbon nanotubes) for AR 18 removal and found Qmax of 166.667mg/g at 7 pH, 25 ^{0}C temperature and 0.02 g sorbent dosage.Lu et al., 2023 prepared an adsorbent, MCGC (Magnetic chitosan cross linked gelatin polymer composites) to remove AR 18 dye and found Qmax of 344.63 mg/g and 99.85% removal efficiency.

Kasraee et al., 2023 developed a novel adsorbent nano-pumice modified with hexa-decyl-tri-methyl ammonium chloridefor AR 18 removal with maximum 99%removal under optimal conditions (pH 4.5, initial concentration 25mg/L, 70 min. of time and 2.375 g/Ldose of nano-

pumice).Ibrahim et al., 2024 used a biosorbent, Yarrowialipolyica NBRC 1658 for 73 % adsorption of AR 18 at 2 pH and 120 minutes contact time.

Amri N. et al., 2022 used electro-coagulated batik sludge (EBS) adsorbent for AR 18 removal from wastewater with Qmax of 51.62 mg/g. Dassi et al., 2017 performed a study to remove AR 18 from textile effluents by combining coagulation/flocculation with adsorption using GAC (granular activated carbon).Adach et al., 2019 studied the usage of Amberlite IRA 478 (polyacrylic anion exchanger) to remove acidic dyes; Acid Red 18 (AR180, Reactive blue (RB21) and Direct Yellow 142 (DY142). Qmax were found to be 1098.5 mg/g for AR 18, 23.5 mg/g for RB21 and 46.8 mg/g for DY142.

Natural materials are available in high abundance and applied for adsorption of AR 18 from water. Shokoohi et al., 2010 used activated carbon derived from poplar wood to effectively remove AR18 from water.Qmax 3.91 mg/g was obtainedat adsorbent dosage 0.8 g, contact time 1 hr, pH 7. Heibati et al., 2015 developedactivated carbon derived from poplar wood (ACP) and walnut wood (ACW). 90 min and 45 min are required for maximum removal of AR 18 dye using ACP (Qmax 3.91) and ACW (Qmax 30.3) at 5 pH.Chaleshtori et al., 2017 used AC prepared from almond shell (AC-AS) for adsorption of AR18 with maximum removal efficiency 90.83 % occurring at pH 2, 60 min. time and 0.8 g/L dose.

Jozwiak & Filipkowska 2024 performed a study to find removal efficiency of novel sorbent prepared from rapeseed husks (RH) for anionic (AR18, AY23) and cationic (BR46, BV10) dyes from water. They studied the effect of various parameters (pH, time, concentration) on maximum adsorption capacity through various batch studies.Qmax was observed to be 49.37 for AR 18 at pH 2.Balarak et al., 2015 used solid waste material, red mud to adsorb AR 18 from water. The optimal conditions for 98.9 % dye removal wasachieved at 3 pH, contact time of 75 minutes, 25 mg/L initial AR 18 concentration and adsorbent dosage of 4 gm/L.Reis et al., 2023 investigated upon usage of nitrogen doped biochar from birch tree wastes for AR 18 dye removal from water and observed Qmax of 545.2 mg/g at pH 6 and 25 ^{o}C temp. with initial concentration of 400 mg/L.

Synthetic and modified synthetic materials have some limitation for effectively used dyes removal adsorbents from water. Environmental sustainability, cost-effectiveness, abundance and availability, high adsorption capacity, regeneration and reusability, safety and non-toxicity are

the key factors for effective adsorbent. Therefore, new natural and modified natural adsorbents are required to fulfill the key factors for adsorption of dyes from water.

3. RESEARCH GAPS

Recently lot of efforts and research is going on for adsorption of toxic contaminants, dyes and other toxic materials from water system. Notable technologies and advanced methods include advanced oxidation processes, advanced filtration techniques, biological and chemical degradation, electrochemical methods, hybrid system, nanotechnology and adsorption. Advance technologies are also helping to address the environmental implication of dyes in water bodies and enhance the efficiency of dye removal processes. These technologies and methods have made significant impacts for controlling water pollution and mitigation of dyes and toxic contaminants from water, still there are various key gaps remain for adsorption of toxic dyes from water.

Although advanced technologies are existed for removing dyes from wastewater, further improvement is required to prepare more efficient, economical, and eco-friendly materials, especially for treating large volumes of dye wastewater. Also alternative dyes and dyeing processes is needed which are eco-friendly to promote sustainable practices in the textile and dyeing industries. Public awareness regarding the impact of dye on environmental and human beings is the key factor to control dye pollution. To minimize the negative effects of dye water pollution on the ecosystem and to advance sustainable water management techniques, it will be imperative to fill in these research gaps. Limited studies have been focused on the sustainability factor and optimization of removal conditions as per the characteristics of water to be treated.

4. PROBLEM STATEMENT

Azo dyes (synthetic dyes)have one or more azo(–N=N–) groups as part of their chemical structure. They are applied in industries, including textiles, leather, paper, cosmetics, and food items.The main concerns regarding azo dyes are their potential impact on water pollution. They are often not fully absorbed by the materials they dye, leading to excess dye being released during washing or disposal. This unabsorbed dye from the industry is entered into water through untreated discharge, where it can persist for a long time and pose various environmental and

health risks**.** Acid Red 18 (AR 18) is a synthetic acidic dye that belongs to the azo dye class. Like other azo dyes, AR 18 can contribute to water pollution if not properly managed.

Addressing acidic dye pollution in water requires a combination of regulatory measures, technological advancements, and a commitment to sustainability from industries and society as a whole. Efforts to mitigate the impact of dyes (especially azo dyes) on water pollution include the development of more sustainable dyeing processes, the use of natural dyes, and the implementation of low cost, environmental friendly adsorbent on the discharge of dye-containing water effluents.

Removing acidic dyes, like Acid Red 18, from water can be challenging due to their structure and solubility. Precipitation, advanced filtration, biological and chemical degradation, ion exchange, and adsorption are effectively applied methods for mitigation of dye from water. The choice of method depends on various factors, including the specific dye, its concentration, the quantity of water to be treated, and the available resources and infrastructure.

Adsorption is a process in which desired particles adhere on the outer part of the solid (Adsorbent). It is very common for water treatment. It is often used to remove contaminants such as dyes from water. Adsorption is useful technique for mitigation of dye and other contaminants on the surface of specific materials. Preparation of new effective adsorbents with high stability, porous structure, cost-effectiveness, and environmental-friendly characteristics is a challenging task till date. Keeping all the points in mind the present work is based on requirements of new eco-friendly cost effective preparation of adsorbent for removal of AR 18 dye from water. Keeping all the points in mind, the present work is based on the requirements of a new eco-friendly, cost-effective and extremely effective materials for the removal of AR-18 dye from the water system.

5. RESEARCH OBJECTIVES

Objectives of the current research are as follows:

1. To propose the newgreenmaterial for Acid Red 18 dye removal from water
2. Synthesis of new modified greenmaterialsfor Acid Red 18 dye removal from water
3. Proposed materials will be characterized using various characterization techniques (Fourier transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), energy dispersive X-ray spectrometer **(**EDS), X-ray diffraction (XRD) techniques etc.

4. Batch study will be performed to get the maximum removal of AR 18 dye on natural and modified natural adsorbents using crucial parameters i.e. pH, dose, time, and concentration etc.

5. Advanced isotherms and kinetics models will be applied to get thefurther information regarding adsorption process.

6. Optimization study will be performed to get the optimal value of removal of AR 18 dye from water

7. Efficiency of proposed materials (adsorbents) will be compared with other reported materials (adsorbents).

6. RESEARCH METHODOLOGY

Various green materials will be explored for removal of Acidic dye from water system. The adsorption performance of selected materials will be checked using preliminary adsorption batch studies after checking the residual concentration of dye in treated water sample followed by characterization of material before and after adsorption.

Facile modification of natural adsorbents will be done to enhance their removal performance.Performance of these adsorbents is identified in terms of removal efficiency. Work is designed on the basis of removal efficiency, cost and eco-friendly nature of the adsorbents for removal of AR 18 from water system. Both natural and modified natural adsorbents will be characterized using spectral techniques. Batch study will be performed to get the maximum removal of AR 18 dye from water at variable parameters i.e. pH, dose, time, and concentration etc. Isotherms and kinetics models will be applied to know adsorption mechanism of AR 18 dye.

Optimization study will be performed to reduce the cost and time of the reaction and getting optimal value of removal of AR 18 dye from water. Efficiency of natural and modified natural adsorbents will be conducted by the performance comparison with similar and synthetic adsorbents.

7. EXPECTED OUTCOMES OF THE RESEARCH

Followings are the expected outcomes of the research works

1. Present work will be helpful to identify the source of AR 18 dye pollution, health and environmental effects and its elimination from water.

2. This work will be identified novel low cost green materials for efficient removal of AR 18 dye

from water.

3. New green modified adsorbents will be helpful to enhance the performance of the material for AR 18 dye

4. Batch study will be helpful to identify the effect of specific parameters i.e. pH, dose, AR 18 dyeconcentration, time of contact, and temperature on adsorption of dye from water. Various isotherm and kinetic models will be helpful to know the proper mechanism of adsorption of AR 18 dye on adsorbents.

6. Optimization study will be helpful to reduce the cost and time of the overall process.

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